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Maeda et al.

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(54) **HIGH PRESSURE PUMP**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**[7] **F04B 39/08**
(52) **U.S. Cl.** **417/505**; 123/506; 251/129.02
(58) **Field of Search** 417/505; 123/506; 251/129.02; 91/275

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Primary Examiner—Cheryl J. Tyler

(57) **ABSTRACT**

A high pressure pump includes a cylinder body. The cylinder body has a cylinder and a valve recess communicated with the cylinder. A cover is attached to the cylinder body to surround the valve recess. A plunger reciprocates in the cylinder. An electromagnetic valve has a pressurizing chamber, a valve hole connected to the pressurizing chamber and a valve body. The valve body selectively opens and closes the valve hole. The electromagnetic valve is fixed to the cover. When fluid is pressurized in the pressurizing chamber, the valve hole is closed by the valve body and the plunger enters the pressurizing chamber. A seal ring is located between an outer surface of the electromagnetic valve and an inner surface of the valve recess. The seal ring seals the pressurizing chamber. This reliably seals a pressurizing chamber and improves the displacement efficiency.

13 Claims, 4 Drawing Sheets

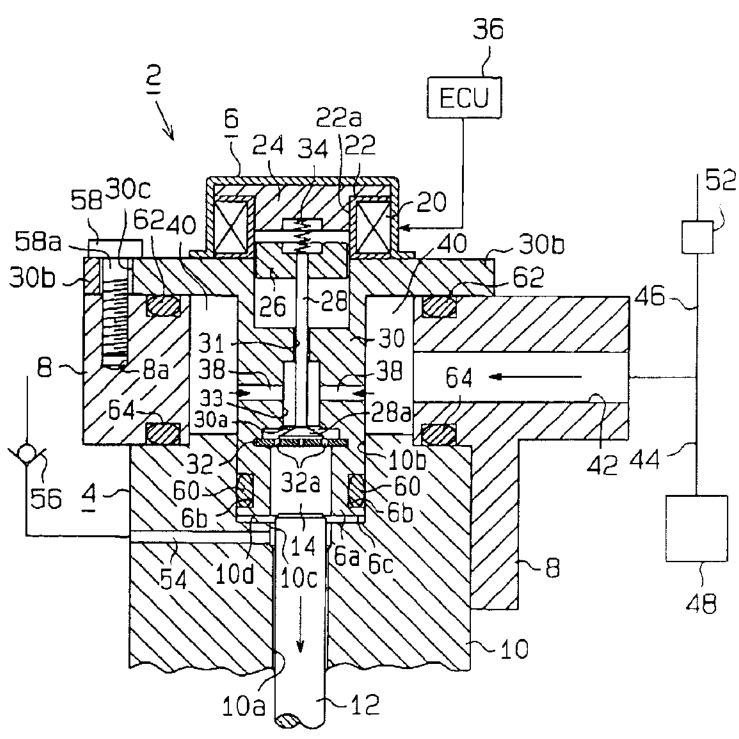
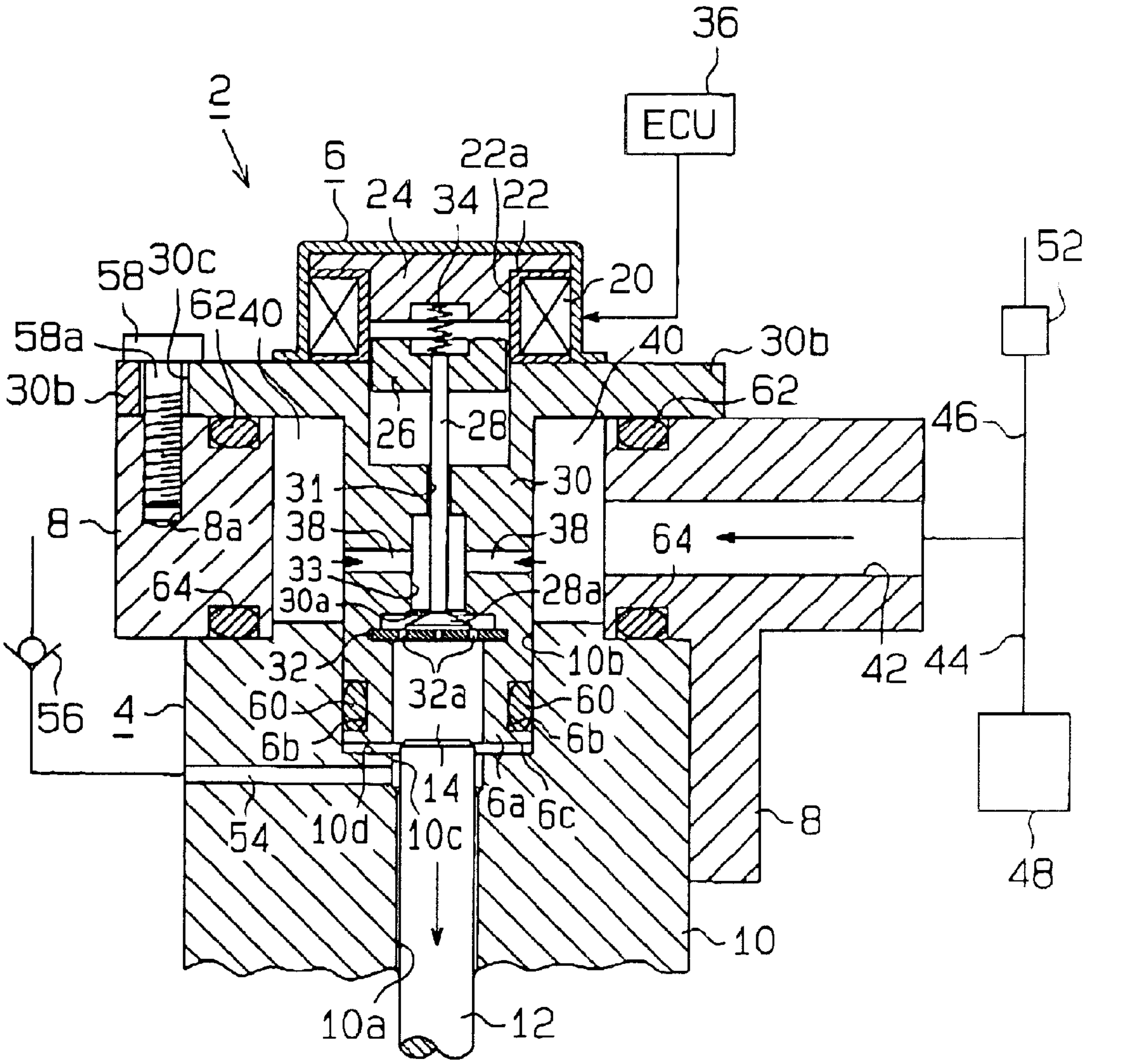


Fig.1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34
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30c
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26
28
8
31
30
38
38
64
8a
33
64
28a
30a
42
44
32
10b
56
4
60
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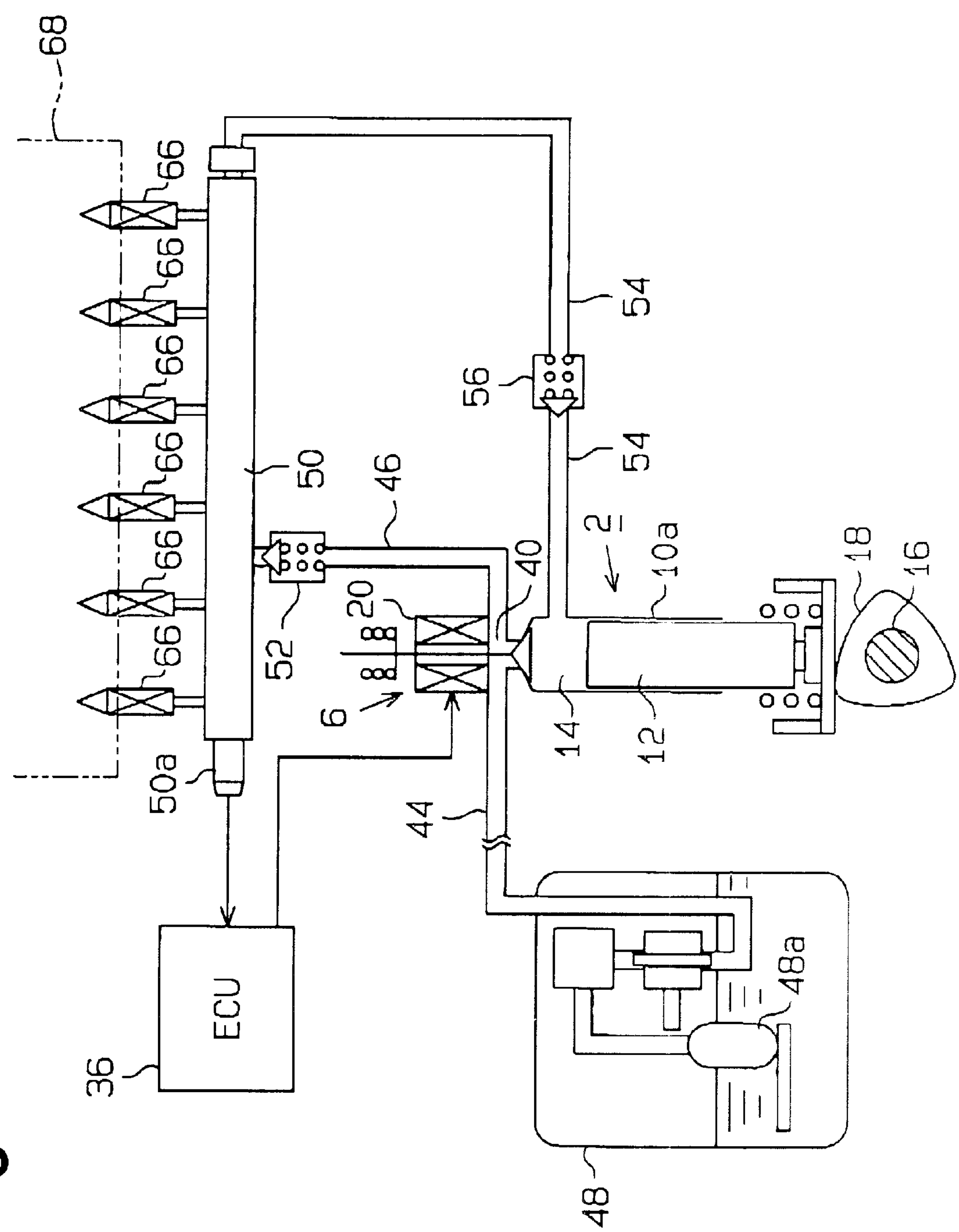
10a
12

Fig. 2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50a
46
52
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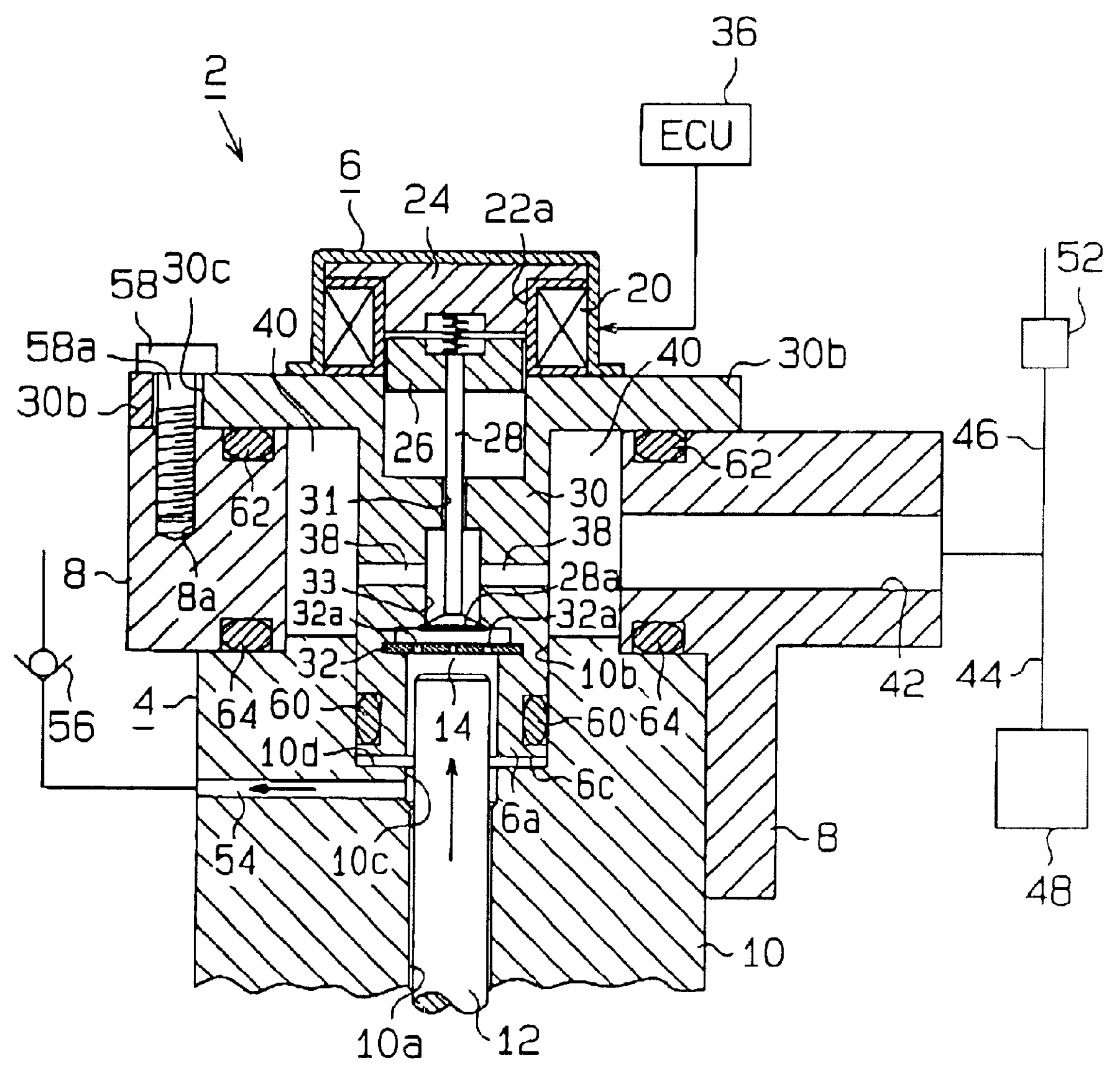
18
16
6
14
12
44
48a
48
36
ECU

Fig.3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58a
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30b
30b
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31
30
38
38
8
8a
33
28a
32a
32a
32
10b
42
44
56
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6c
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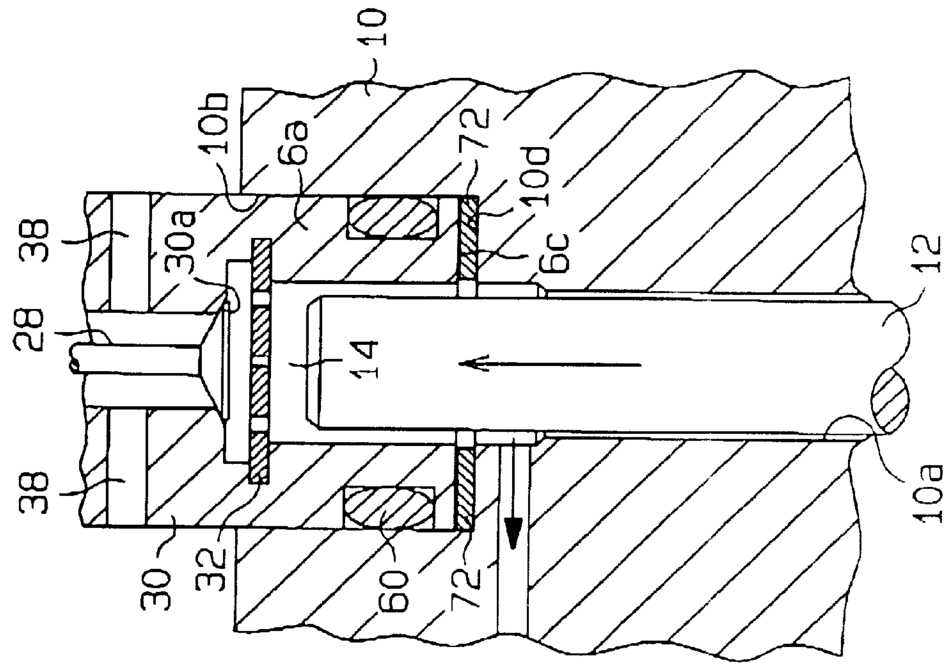
10a
12

Fig.4(B)


10
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6c
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14
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30
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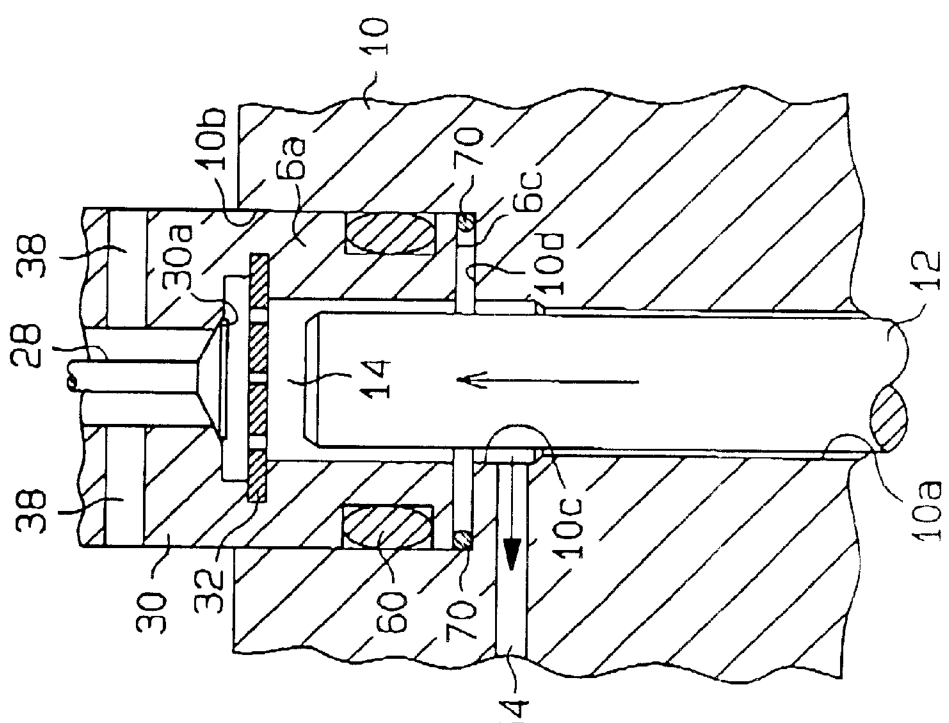
60
72

Fig.4(A)


10
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6a
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6c
38
30a
10d
12
28
14
38
10c
10a
30
32
60
70
54

HIGH PRESSURE PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a high pressure pump. More particularly, the present invention pertains to a high pressure pump that includes an electromagnetic valve that selectively opens and closes a pressurizing chamber defined adjacent to a cylinder in a cylinder body.

Japanese Unexamined Patent Publication No. 8-14140 discloses a high pressure pump that pressurizes fuel supplied to an internal combustion engine. This pump includes a plunger that is located in a cylinder, which is defined in a cylinder body. A pressurizing chamber is defined in the cylinder body adjacent to the plunger. The plunger is reciprocated to pressurize fuel in the pressurizing chamber. An electromagnetic valve is located adjacent to the pressurizing chamber. The valve is controlled to adjust the displacement of the pump.

A washer and a gasket are located between the opening of the cylinder and an end of the electromagnetic valve to seal the pressurizing chamber. The washer and the gasket are tightly held between the body of the valve the opening of the cylinder to so that the pressurizing chamber is reliably sealed. In other words, a relatively high pressure is applied to the opening of the cylinder, which may deform the cylinder. Since the cylinder is machined with a high precision, the deformation increases the friction between the cylinder and the plunger. Also, the orientation of the plunger may be displaced, which prevents smooth motion of the plunger.

To reduce the friction between the inner wall of the cylinder and the surface of the plunger, the clearance between the cylinder and the plunger must be relatively great to compensate for deformation of the cylinder. However, a greater clearance causes liquid to leak from the pressurizing chamber, which lowers the discharge efficiency of the high pressure pump.

BRIEF SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a high pressure pump that reliably seals a pressurizing chamber and improves the displacement efficiency.

To attain the above-mentioned object, the present invention provides a high pressure pump. The high pressure pump includes a cylinder body. The cylinder body has a cylinder and a communication hole communicated with the cylinder. A cover is attached to the cylinder body to surround the communication hole. A plunger reciprocates in the cylinder. An electromagnetic valve has a pressurizing chamber, a valve hole connected to the pressurizing chamber and a valve body for selectively opening and closing the valve hole. The electromagnetic valve is fixed to the cover. When fluid is pressurized in the pressurizing chamber, the valve hole is closed by the valve body and the plunger enters the pressurizing chamber. A seal ring is located between an outer surface of the electromagnetic valve and an inner surface of the communication hole. The seal ring seals the pressurizing chamber.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. **1** is a cross-sectional view illustrating a high pressure pump according to a first embodiment of the present invention;

FIG. **2** is a diagram illustrating the fuel supply system of an internal combustion engine that has the high pressure pump of FIG. **1**;

FIG. **3** is a cross-sectional view like FIG. **1** when the valve body of the high pressure pump closes the valve hole;

FIG. **4**(A) is a cross-sectional view illustrating a high pressure pump according to a second embodiment, and

FIG. **4**(B) is a cross-sectional view illustrating a high pressure pump according to a third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A high pressure pump **2** according to a first embodiment of the present invention will now be described with reference to FIGS. **1** to **3**.

As shown in FIG. **1**, the high pressure pump **2** includes a pump mechanism **4** and an electromagnetic valve **6**. The pump mechanism **4** includes a cover **8**, a cylinder body **10** and a plunger **12**. A cylinder **10***a* extends axially in the cylinder body **10**. A valve recess **10***b* is formed adjacent to the upper end of the cylinder **10***a*. The cover **8** is located on the cylinder body **10** and surrounds the valve recess **10***b*.

The electromagnetic valve **6** has a cylindrical portion **6***a* at the lower end portion. The cylindrical portion **6***a* is received by the recess **10***b*. A pressurizing chamber **14** is defined in the cylindrical portion **6***a*.

A plunger **12** is located in the cylinder **10***a* and is reciprocated by a cam **18**, which is attached to a camshaft **16** (see FIG, **2**). When reciprocated, the plunger **12** protrudes into and retracted from the pressurizing chamber **14**.

The electromagnetic valve **6** includes an annular coil **20**, a bobbin **22**, a stationary core **24**, an armature **26**, a poppet valve **28**, a housing **30** and a stopper **32**. The cylindrical portion **6***a* is formed in the lower portion of the housing **30**. The coil **20** is wound about the bobbin **22**. The bobbin **22** has a through hole **22***a*. The core **24** is fitted in the through hole **22***a* of the bobbin **22**.

The armature **26** is fixed to the upper end of the shaft of the poppet valve **28**. The armature **26** and the core **24** are coaxial and can enter the through hole **22***a* of the bobbin **22**. A compressed spring **34** is located between the core **24** and the armature **26**. The spring **34** urges the armature **26** and the poppet valve **28** toward the pressurizing chamber **14**.

The shaft of the poppet valve **28** extends through a shaft hole **31** formed in the housing **30**. The poppet valve **28** has a substantially conical valve body **28***a*. A valve hole **33** is formed in the electromagnetic valve **6**. The valve hole **33** is opened and closed by the valve body **28***a*. When current is not supplied to the coil **20**, the valve body **28***a* is separated from a valve seat **30***a,* which is defined about the lower opening of the valve hole **33** in the housing **30**, by the force of the spring **34** and abuts the stopper **32**. At this time, the valve hole **33** is opened. When an electronic control unit (ECU) **36** supplies current to the coil **20**, the core **24**, the armature **26** and the housing **30** produce a magnetic circuit. As a result, the armature **26** is moved toward the core **24** against the force of the spring **34**. Accordingly, the poppet valve **28** separates from the stopper **32** and the valve body **28***a* contacts the valve seat **30***a*. At this time, the valve hole **33** of the electromagnetic valve **6** is closed.

As shown in FIGS. **1** and **3**, the stopper **32** faces the valve body **28***a* of the poppet valve **28**. Supply passages **38** are formed in the housing **30**. Holes **32***a* are formed in the stopper **32**. The holes **32***a* permit flow of fuel. When the electromagnetic valve **6** is opened as shown in FIG. **1**, the holes **32***a* permit fuel to flow between the supply passages **38** and the pressurizing chamber **14**.

A gallery **40** is defined between the housing **30** and the cover **8**. A supply passage **38** is formed in the cover B. The supply passages **38** are connected to a low pressure passage **44** and a return passage **46** by the gallery **40** and the fuel passage **42**. The low pressure passage **44** is connected to a fuel tank **48**. As shown in FIG. **2**, the high pressure fuel pump **2** receives fuel from a feed pump **48***a* in the fuel tank **48**. The return passage **46** is connected to a relief valve **52**. The relief valve **52** returns excess fuel from a fuel distribution pipe **50** to the pressurizing chamber **14**. The high pressure fuel pump **2** reuses fuel that is returned from the distribution pipe **50** through the relief valve **52**.

As shown in FIGS. **1** and **3**, a large diameter portion **10***c* is formed in the upper portion of the cylinder **10***a*. The pressurizing chamber **14** communicates with the large diameter portion **10***c*. A high pressure passage **54**, a part of which is formed in the cylinder body **10**, is connected to the pressurizing chamber **14** through the large diameter portion **10***c*. In the cylinder body **10**, the high pressure passage **54** extends perpendicular to the pressurizing chamber **14**. A check valve **56** is located in the high pressure passage **54**. The pressurizing chamber **14** is connected to the fuel distribution pipe **50** by the high pressure passage **54** and the check valve **56**.

The check valve **56** permits fuel to flow from the pressurizing chamber **14** to the fuel distribution pipe **50**. The check valve **56** also prevents fuel from flowing from the distribution pipe **50** to the pressurizing chamber **14**. If the plunger **12** projects into the pressurizing chamber **14** when the electromagnetic valve **6** is closed, pressure of fuel in the pressurizing chamber **14** is increased. At this time, the pressurized fuel is sent to the distribution pipe **50** through the high pressure passage **54** and the check valve **56**. When the plunger **12** is retracted from the pressurizing chamber **14**, fuel is drawn to the pressurizing chamber **14** from the fuel passage **42** through the gallery **40**, the supply passage **38** and the holes **32***a*.

A flange **30***b* is formed in the upper portion of the housing **30**. Bolt holes **30***c* (only one is shown in FIG. **1**) are formed in the flange **30***b*. Threaded holes **8***a,* the number or which corresponds to the number of the bolt holes **30***c,* are formed in the cover **8**. A bolt **58** extends through each bolt hole **30***c* and threaded to the corresponding threaded hole **8***a,* which fastens the electromagnetic valve **6** to the pump mechanism **4**.

The diameter of each bolt hole **30***c* is greater than the diameter of the shaft **58***a* of each bolt **58** by a predetermined value. Therefore, before the bolts **58** are fastened tightly to the threaded holes **8***a,* the housing **30** can be moved relative to the cover **8** within a predetermined range. The housing **30** is fixed to the cover **8** by fastening the bolts **58**.

An annular groove **6***b* is formed in the circumference of the cylindrical portion **6***a* of the electromagnetic valve **6**. An O-ring **60** is fitted in the groove **6***b*. The O-ring **60** is elastically deformed and is supported between the surface of The cylindrical portion **6***a* and the recess **10***b* to seal the pressurizing chamber **14**. The O-ring **60** is made of elastic material such as silicone rubber.

The electromagnetic valve **6** is installed in the following manner. First, the cover **8**, the cylinder body **10** and other parts are integrated by an assembler (not shown) to form a pump mechanism **4**.

Then, the cylindrical portion **6***a* of the electromagnetic valve **6** is inserted into the recess **10***b* of the cylinder body **10**. A small clearance exists between the cylindrical portion **6***a* and the recess **10***b*. However, the O-ring **60**, which is fitted about the cylindrical portion **6***a,* contacts the recess **10***b* and is elastically deformed to seal the pressurizing chamber **14**. As the O-ring **60** is deformed, the axis of the cylindrical portion **6***a* matches with the axis of the recess **10***b*.

Since the diameter of the bolt holes **30***c* is greater than that of the shafts **58***a* of the bolts **58**, the cylindrical portion **6***a* can be moved radially within a predetermined range even if the bolts **58** is partially engaged with the threaded holes **8***a*. Therefore, the position of the cylindrical portion **6***a* is determined by the O-ring **60**. Thereafter, the bolts **58** are fastened to fix the flange **30***b* to the cover **8**.

The gallery **40** is sealed by an O-ring **62** that is located between the cover **8** and the flange **30***b* and an O-ring **64** that is located between the cover **8** and the cylinder body **10**.

As shown in FIG. **2**, the high pressure fuel pump **2** is used in a fuel supply system of an in-cylinder fuel injection type gasoline engine **68**. In the engine **68**, fuel is directly injected into combustion chambers (not shown). When the engine **68** is running, the camshaft **16**, which is coupled to the crankshaft, is rotated. Accordingly, the cam **16** is rotated, which reciprocates the plunger **12** in the cylinder **10***a*. When the plunger **12** is moved downward away and retracts from the pressurizing chamber **14** as shown by an arrow in FIG. **1**, the volume of the pressurizing chamber **14** is increased. This stroke is referred to as suction stroke. In the suction stroke, fuel is supplied to the pressurizing chamber **14** from the low pressure passage **44** or from the return passage **46** through the fuel passage **42**, the gallery **40**, the supply passage **38** and the holes **32***a*.

When the plunger **12** is moved upward into the pressurizing chamber **14**, the volume of the pressurizing chamber **14** is decreased. This stroke will be referred to as a pressurizing stroke. If the electromagnetic valve **6** is opened during a pressurizing stroke, fuel in the pressurizing chamber **14** is returned to the fuel passage **42** through the holes **32***a,* the supply passage **38** and the gallery **40**. The valve body **28***a* of the poppet valve **28** closes the valve hole **33** at an appropriate timing during the pressurizing stroke, which raises the pressure in the pressurizing chamber **14**. The pressurized fuel in the pressurizing chamber **14** is supplied to the fuel distribution pipe **50** through the high pressure passage **54**, the check valve **56**. Accordingly, the pressurized fuel is supplied to fuel injectors **66**, which are shown in FIG. **2**. That is, fuel is supplied to each fuel injector **66** when the corresponding compression chamber is in the compression stroke. The timing at which the electromagnetic valve **6** closes the valve hole **33** is controlled by the ECU **36** in accordance with the pressure detected by a fuel pressure sensor **50***a* located in the distribution pipe **50** and the amount of fuel injected from the fuel injectors **66**. In this manner, the flow rate of pressurized fuel that is sent from the high pressure pump **2** to the distribution pipe **50** is controlled such that the pressure of injected fuel is appropriate.

The embodiment of FIGS. **1** to **3** has the following advantages.

The pressurizing chamber **14** is sealed by the O-ring **60**, which is located between the cylindrical portion **6***a* of the electromagnetic valve **6** and the recess **10***b*. Therefore, unlike the prior art high pressure valves, the electromagnetic valve **6** need not be pressed in the axial direction toward the cylinder body **10**. Thus, the part surrounding the cylinder **10***a* does not receive load from the valve **6**. As a result, the cylinder **10***a* is not deformed.

The pressurizing chamber **14** is sealed without deforming the cylinder **10***a*. Thus, the clearance between the cylinder **10***a* and the plunger **12** can be reduced, which increases the discharge efficiency.

The cylindrical portion **6***a* of the electromagnetic valve **6** is inserted into the recess **10***b* of the cylinder body **10**. The volume of the pressurizing chamber **14** is relatively small. Specifically, the volume of the pressurizing chamber **14** is smaller than the volume of the recess **10***b* substantially by the volume of part of the cylindrical portion **6***a* that is located in the recess **10***b*. Therefore, as the plunger **12** strokes, the pressure of fuel in the pressurizing chamber **14** is quickly increased, which improves the discharge efficiency.

When the plunger **12** projects into the pressurizing chamber **14**, the plunger **12** must be accurately guided into the pressurizing chamber **14** by the cylinder **10***a*. In the embodiment of FIGS. **1** to **3**, the cylinder **10***a* is prevented from being deformed. Thus, the plunger **12** is accurately and easily guided into the pressuring chamber **14** by the cylinder **10***a*.

The clearance between the pressurizing chamber **14** and the plunger **12** can be reduced. Accordingly, the volume of the pressurizing chamber **14** is reduced, which improves the discharge efficiency.

The O-ring **60** is located between the outer surface of the electromagnetic valve **6** and the wall of the recess **10***b*. When the electromagnetic valve **6** is installed by inserting the cylindrical portion **6***a* into the recess **10***b* of the cylinder body **10**, the elastic force of the O-ring **60** equally acts on the cylinder body **10** in the radial directions. Therefore, the axis of the cylindrical portion **6***a* is matched with the axis of the recess **10***b*.

In other words, the O-ring **60** permits the electromagnetic valve **6** to be accurately installed in the cylinder body **10**. Also, the diameter of the bolt holes **30***c* is greater than the diameter of the shafts **58***a* of the bolts **58**. Therefore, the shape and the position of each bolt **58** need not be highly accurate. That is, the bolts **58** do not require high machining accuracy. Also, the position of each threaded hole **8***a* need not be highly accurate. This structure reduces the machining cost of the high pressure pump **2**.

Since the valve **6** is installed with a high accuracy in the recess **10***b*, the clearance between the pressurizing chamber **14** and the plunger **12** can be reduced compared to the prior art pumps. As a result, leak of fuel from the pressurizing chamber **14** is reduced. Thus, as the plunger **12** strokes, the pressure of fuel is quickly increased, which improves the discharge efficiency.

The electromagnetic valve **6** is fixed to the cover **8**, which is separately formed from the cylinder body **10**. Therefore, deformation of the cylinder **10***a* due to installation of the electromagnetic valve **6** is decreased. As a result, the clearance between the cylinder **10***a* and the plunger **12** can be further reduced, which improves the discharge efficiency.

FIG. **4**(A) illustrates a second embodiment. The second embodiment is different from the embodiment of FIGS. **1** to **3** in that an annular absorber **70** is located between the lower face **6***c* of the cylindrical portion **6***a* of the electromagnetic valve **6** and the bottom **10***d* of the recess **10***b*. The absorber **70** prevents pressure pulsation.

The absorber **70** is made of a material that is durable against fuel and pressure pulsation. For example, the absorber **70** is made of a metal or a resin. The axial dimension of the absorber **70** is determined such that the force of the absorber **70** does not deform the cylinder **10***a*. For example, axial dimension of the absorber **70** is smaller than the distance between the lower face **6***c* and the bottom **10***d*.

FIG. **4**(B) illustrates a third embodiment. In the third embodiment, an annular absorber **72** that has a rectangular cross section is used.

In addition to the advantages of the embodiment shown in FIGS. **1** to **3**, the embodiments of FIGS. **4**(A) and **4**(B) have the following advantages.

If the valve body **28***a* of the poppet valve **28** contacts the valve seat **30***a* when the plunger **12** is being pressurizing fuel in the pressurizing chamber **14**, the pressure of the fuel is abruptly increased. Then, pressure pulsation is transmitted from the pressurizing chamber **14** to the O-ring **60** through the space between the cylindrical portion **6***a* and the recess **10***b*. However, the absorbers **70**, **72** of FIGS. **4**(A) and **4**(B) prevent pressure pulsation from being transmitted to the O-ring **60**. Therefore, wear of the O-ring **60** is reduced, which extends the life of the O-ring **60**.

The present invention may be applied to other types of high pressure pumps. For example, the present invention may be applied to a high pressure pump that changes the displacement by adjusting the opening timing of an electromagnetic valve during suction stroke to control the amount of fuel that is drawn to a pressurizing chamber.

The present invention may be applied to a high pressure pump that pressurizes fluid other than fuel.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

What is claimed is:

1. A high pressure pump comprising:

a cylinder body, wherein the cylinder body has a cylinder and a communication hole communicated with the cylinder;

a cover attached to the cylinder body to surround the communication hole;

a plunger that reciprocates in the cylinder;

an electromagnetic valve having a pressurizing chamber, a housing attached to the cover, wherein the housing has a valve seat and a valve hole connected to the pressurizing chamber, and a valve body for selectively contacting to and separating from the valve seat to selectively open and close opening and closing the valve hole, wherein the electromagnetic valve is fixed to the cover, wherein, when fluid is pressurized in the pressurizing chamber, the valve hole is closed by the valve body and the plunger enters the pressurizing chamber; and

a seal ring located between an outer surface of the electromagnetic valve and an inner surface of the communication hole, wherein the seal ring seals the pressurizing chamber,

wherein the electromagnetic valve has a cylindrical portion, which is located in the communication hole, wherein the pressurizing chamber is formed in the cylindrical portion, and wherein the seal ring is located between an outer surface of the cylindrical portion and the inner surface of the communication hole.

2. The high pressure pump according to claim **1**, wherein the seal ring positions the electromagnetic valve such that the communication hole and the electromagnetic valve are coaxial.

3. The high pressure pump according to claim **1**, wherein, when the valve hole is opened by the valve body, the valve body enters the pressurizing chamber, wherein, when the valve hole is closed, the valve body is away from the pressurizing chamber.

4. The high pressure pump according to claim **1**, wherein an absorber is located between the inner surface of the communication hole and the outer surface of the cylindrical portion, wherein the absorber prevents transmission of pressure pulsation to the seal ring.

5. The high pressure pump according to claim **1**, wherein the seal ring is O-ring made of rubber.

6. The high pressure pump according to claim **1**, wherein a part that the electromagnetic valve corresponds to the seal ring is exposed to the pressurizing chamber.

7. A high pressure pump comprising:

a cylinder body, wherein the cylinder body has a cylinder and a communication hole communicated with the cylinder;

a cover attached to the cylinder body to surround the communication hole, wherein the cover has a through hole;

a plunger that reciprocates in the cylinder;

an electromagnetic valve having a pressurizing chamber, a housing attached to the cover, wherein the housing has a valve seat and a valve hole connected to the pressurizing chamber, and a valve body for selectively contacting to and separating from the valve seat to selectively open and close opening and closing the valve hole, wherein, when fluid is pressurized in the pressurizing chamber, the valve hole is closed by the valve body and the plunger enters the pressurizing chamber;

a fastener located in the through hole cover, wherein the fastener fixes the electromagnetic valve to the cover; and a seal ring located between an outer surface of the electromagnetic valve and an inner surface of the communication hole, wherein the seal ring seals the pressurizing chamber,

wherein the electromagnetic valve has a cylindrical portion, which is located in the communication hole, wherein the pressurizing chamber is formed in the cylindrical portion, and wherein the seal ring is located between an outer surface of the cylindrical portion and the inner surface of the communication hole.

8. The high pressure pump according to claim **7**, wherein the fastener is annular, and wherein the diameter of the through hole is greater than outer diameter of the fastener.

9. The high pressure pump according to claim **7**, wherein the seal ring positions the electromagnetic valve such that the communication hole and the electromagnetic valve are coaxial.

10. The high pressure pump according to claim **7**, wherein, when the valve hole is opened by the valve body, the valve body enters the pressurizing chamber, wherein, when the valve hole is closed, the valve body is away from the pressurizing chamber.

11. The high pressure pump according to claim **7**, wherein an absorber is located between the inner surface of the communication hole and the outer surface of the cylindrical portion, wherein the absorber prevents transmission of pressure pulsation to the seal ring.

12. The high pressure pump according to claim **7**, wherein the seal ring is O-ring made of rubber.

13. The high pressure pump according to claim **7**, wherein a part that the electromagnetic valve corresponds to the seal ring is exposed to the pressurizing chamber.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,554,590 B2
DATED : April 29, 2003
INVENTOR(S) : Tomoyuki Maeda et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2,
Line 36, change "(see **FIG, 2**)." to -- (see **FIG. 2**). --.

Column 3,
Line 8, change "cover B." to -- cover **8**. --.
Line 63, change "The cylindrical" to -- the cylindrical --.

Column 4,
Line 27, change "cam **16**" to -- cam **18** --.

Signed and Sealed this

Thirtieth Day of March, 2004

JON W. DUDAS
Acting Director of the United States Patent and Trademark Office